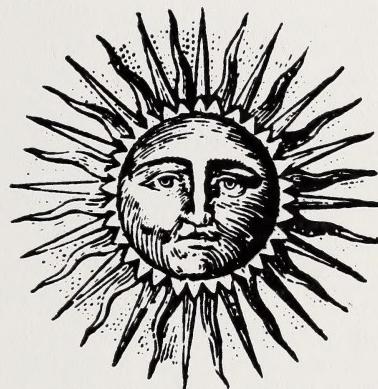


AL 2.1988-261

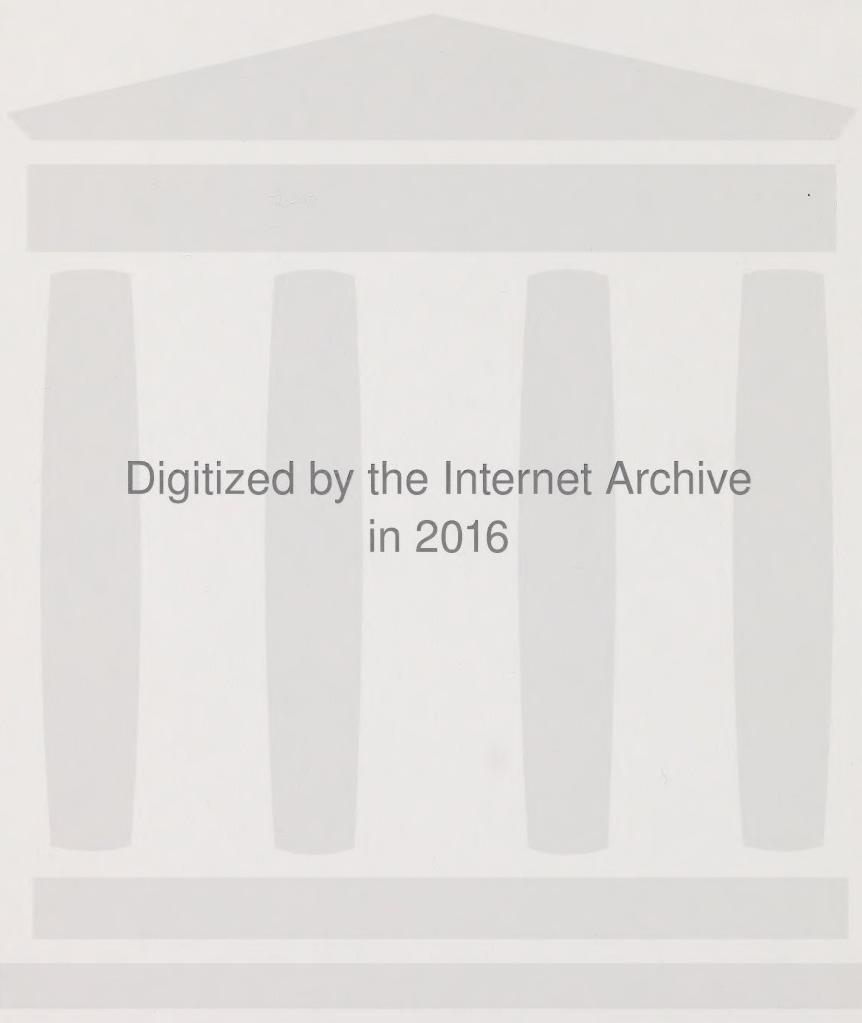
CANADIANA
Q
SEP 23 1988

Renewable Energy

THE POWER AND THE POTENTIAL



A discussion paper prepared for the Alberta
Conservation Strategy Project



Digitized by the Internet Archive
in 2016

<https://archive.org/details/renewableenergyp00snyd>

Renewable Energy

The Power and the Potential

Prepared by *enriched by Allevans, and Allevans has been recommended as an excellent media*

**Energy and Non-Renewable Resources Sub-Committee
of the Public Advisory Committees
to the Environment Council of Alberta**

Published by Environment Council of Alberta



to support the project, through public hearings or some other public participation process.

 The last section of the prospectus, the *Investor Information*, provides sections on previous research and discussion papers, as well as a summary of Strategic Planning Committee findings related to our products, including papers on relevant aspects, such as against-use, fish and wildlife, toxicology, air and gas, and severe. These discussion papers look at the longer-term impacts of our products, but, more importantly, they investigate the im-

August 1988 The presenters have developed a programme with a wide range of activities, including lectures, —totally new processes intended to develop

 Alberta
ENVIRONMENT COUNCIL OF ALBERTA

Distributed without charge as a public service.

Additional copies of this publication may be obtained from:

Environment Council of Alberta
8th Floor Weber Centre
5555 Calgary Trail Southbound NW
Edmonton, Alberta
T6H 5P9

Phone (403)427-5792

Orders may also be placed through our electronic bulletin board at (403)438-5793 (24 hours per day).

This report may be cited as:

Energy and Non-Renewable Resources Sub-Committee, Public Advisory Committees to the Environment Council of Alberta. 1988. *Renewable Energy: The Power and the Potential.* ECA88-PA/CS-S7. Environment Council of Alberta, Edmonton.

FOREWORD

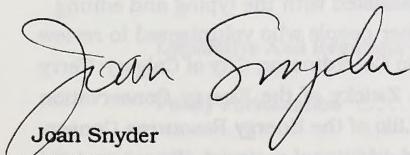
In late 1985, the Public Advisory Committees to the Environment Council of Alberta began working toward a draft conservation strategy for Alberta. The Public Advisory Committees (PACs), comprising representatives of some 120 non-government organizations, are in many ways an ideal organization for developing a strategy that should touch the lives of all Albertans. The PACs bring together many diverse viewpoints, we are non-partisan, and we have members from across the province. Since the early days of the project, we have welcomed non-PAC participants, and have been delighted to receive the contributions of civil servants, industry spokespeople, academics, and the general public.

We have made progress since 1985: the *Prospectus for an Alberta Conservation Strategy* has been published and many meetings and workshops have been held. The principle of a conservation strategy increasingly has been endorsed by Albertans, and Alberta has been recognized across Canada as a leader in conservation strategy development. There have been important related events. For example, in September of 1987, every environment minister in Canada endorsed the final report of the National Task Force on Environment and Economy, which recommended that conservation strategies be in place in every province and territory by 1992. This same report was endorsed by the First Ministers at their November, 1987 meeting.

We will have a conservation strategy for Alberta, we hope by 1990, the Canadian Year of the Environment. Our work continues in the expectation that all those who are interested will have a chance to contribute to the project, through public hearings or some other public participation process.

Since the publication of the *Prospectus*, the PACs have concentrated on preparing sectoral discussion papers. The Conservation Strategy Steering Committee determined early on to produce background papers on relevant sectors, such as agriculture, fish and wildlife, tourism, oil and gas, and others. These discussion papers look at the issues within each sector, but, more importantly, they investigate the interaction of each sector with the others. Their preparation has involved consulting with a wide range of interest groups — a conservation strategy principle in action — which has proven fruitful in developing ideas about the ultimate conservation strategy. These discussion papers will be used as background information for drafting a conservation strategy document and, perhaps, in the future, in public hearings on the draft conservation strategy. This report is one in the series of discussion papers.

Because there are as many opinions on our best future direction as there are Albertans, we welcome comments. The conservation strategy will be only as good as the work that goes into preparing it. Please address any comments on this discussion paper or others in the series to the Environment Council of Alberta at the address given on the page opposite. I would also encourage you to make your opinions known at public hearings or other events as they are held. Let's treat Alberta as if we plan to stay!



Joan Snyder
Chairperson

Conservation Strategy Steering Committee
Public Advisory Committees to the Environment Council of Alberta

ABOUT THIS DISCUSSION PAPER

Development of Alberta's renewable energy sources — the energy provided by water, wind, sun, biomass, and waste materials, or recoverable as geothermal energy from deep underground — could extend the life of Alberta's fossil fuels and provide energy for Alberta after the non-renewables have been depleted. This paper explores these renewable energy sources, except for hydro energy, which will be covered in a paper on electricity. Their present and potential economic significance is discussed, as well as their capability to meet Alberta's demand for the services that energy can provide.

The impact that renewable energy sources will have on Alberta depends on a great many factors. Important among these are our ability and willingness to use energy much more efficiently; our ability to match the quality of energy supplied to the quality of energy required; and recognition that renewable energy projects, although usually individually small in scale, together can supply a significant amount of power. The paper discusses the changing demand for energy, the steps that might be taken to increase the contribution of "renewables" to meeting these demands, and the interactions that renewable energy developments might have with other resource users.

Eventually, Alberta's supply of fossil fuels will be harder to find or more expensive to develop. Renewable energy sources will play an increasingly important role. The intent of this paper is to stimulate thinking about energy alternatives and the most appropriate ways to move Alberta toward a sustainable energy future.

ACKNOWLEDGEMENTS

The Energy and Non-Renewable Resources Sub-Committee of the Public Advisory Committees to the Environment Council of Alberta is pleased to provide this discussion paper to the public of Alberta. Over the past several years, the Sub-Committee has had many speakers attend its meetings to discuss various aspects of energy use and policy. The information provided by these speakers has shaped in many ways the attitudes and views of Sub-Committee members and thus has influenced the content of this report. A paper by John Hughes, prepared for the Northern Alberta Chapter of the Solar Energy Society of Canada, Inc., provided the launching place for this paper. The Sub-Committee owes a special thanks to Betty Paschen, who has been the energy sector representative on the Alberta Conservation Strategy Steering Committee, and to members of the Sub-Committee who took the time to put their ideas in writing. John Lilley of the Environment Council staff provided very able assistance with research, compilation of information, and writing of this paper and other ECA staff assisted with the typing and editing.

The Sub-Committee also wishes to thank several other people who volunteered to review this paper. John Hughes; Glen Furse, Energy Conservation Co-ordinator, City of Calgary; Terry Montgomery, Sanitation Division, City of Calgary; Lynn Zwicky of the Energy Conservation Branch of the Alberta Department of Energy; and Harry Lillo of the Energy Resources Conservation Board provided useful comments, suggestions, and additional material. We are grateful to these people for their contributions; nevertheless, the contents of this paper remain the responsibility of the Sub-Committee and do not necessarily reflect the views of these people whom we gratefully acknowledge.

Contents

Introduction	1
Early Energy Crises	2
A Revival in Renewable Energy	3
Renewable Energy Sources	4
Solar Energy	4
Wind Energy	6
Geothermal Energy	8
Biomass Energy	8
Energy from Waste	10
Economic Significance	12
Solar Energy	12
Wind Energy	12
Geothermal Energy	13
Biomass Energy	13
Energy from Waste	14
Other Considerations	14
Demand Projections	15
Achieving Sustainable Use	17
Low-Temperature Space Heating	18
Industrial Process Heat	18
Liquid Fuels	18
Electricity	19
Interactions With Competing Users For The Same Resource	20
Solar Energy	20
Wind Energy	21
Geothermal Energy	21
Biomass Energy	21
Energy From Waste	22
Legislative And Regulatory Regime	23
Policy Formulation	24
Conclusion	27
References	28
Members of the Energy and Non-Renewable Resources Sub-Committee	30

Units of Measurement

Various units of measurement for energy and power are used in this report. Some useful information about these units is given below.

Energy

The basic unit of energy in the International System of metric measurement is the joule. It is defined as *the work done when the point of application of a force of one newton is displaced a distance of one meter in the direction of the force*. As in other metric measurement systems, prefixes are used to indicate order of magnitude:

kilo-	10^3	kJ	thousands of joules
mega-	10^6	MJ	millions of joules
giga-	10^9	GJ	billions of joules
tera-	10^{12}	TJ	trillions of joules
peta-	10^{15}	PJ	quadrillions of joules

Energy can also be measured by watt hours, a metric measurement not favored by the International System, but commonly used. Large numbers of watt hours are also expressed using the prefixes given above, for example, kilowatt hours (kwh), meaning units of one thousand watt hours. Some useful conversion factors are:

$$1 \text{ watt second} = 1 \text{ joule}$$

$$1 \text{ kilowatt hour} = 3.6 \text{ megajoules}$$

Power

Power is measured in watts. A watt is defined as *the power required to produce energy at the rate of one joule per second*. Large amounts of power are described using the metric prefixes given above, for example, 40 kilowatts (kw) is 40,000 watts.

Chapter One

Introduction

Alberta's geological legacy has meant that fossil fuels are abundantly available, at relatively low cost during recent decades.

Alberta owes much of its present development, lifestyle, and demographics to the exploitation of these non-renewable energy sources. But fossil fuels will become less readily available, and more costly to develop and use. Renewable resources will become more important as alternative energy sources, but how successful renewable energy sources will be in supplying future energy demands will depend on the actions we take now to encourage or discourage their development.

Any distance we can go in developing our renewable resources and in using all energy sources more wisely will conserve our non-renewable energy sources for more critical uses. Action now will ease the transition from a dependence on non-renewable sources to more use of sustainable renewable energy.

This paper explores the economic and social significance and other aspects of the use of renewable energy to supply future energy demands. The sources of renewable energy discussed include solar, wind, geothermal, biomass, and energy from waste. Hydroelectric potential is not discussed nor is the very important role of reducing energy demand. These aspects are covered in other papers in the conservation strategy series, on electricity and conserving energy respectively. Other aspects of energy supply and demand relating to Alberta's non-renewable resources are the subject of oil and gas, and coal sector papers.

Renewable energy sources are those resources which are continuously available or which regenerate or "renew" themselves within a reasonable time frame. This does not mean that

a renewable resource is unlimited. The wood resource is renewable, but if forests are overharvested, it can be depleted. Solar energy, however, is essentially inexhaustible because the sun will continue to produce light and heat energy for several billion years. Wind is renewable because it is caused by the rotation of the earth and by temperature differentials in the atmosphere.

Strictly speaking, there is no such thing as "renewable" energy. The dissipation of energy is an irreversible process. What this means is that the total supply of usable energy is constantly and inevitably being lost. So although we refer to energy from the sun and wind as "renewable," this is something of a misnomer. Energy continues to be available from these sources, but it is not the same energy that was available yesterday or last year.

If energy continuously degrades into less available forms, it is logical, and more efficient, to supply energy in the least concentrated form that meets a particular demand. A joule of electricity can be used for many more things than a joule of low-temperature heat, because the energy is more concentrated in electricity. But it takes a lot more energy to produce electricity than it does to provide heat. If heat is what is needed, then it is sensible to supply heat, instead of using energy to produce electricity and then using the electricity to produce heat.

Making the most of the energy supply means using energy appropriately, or following what is often called a "soft energy path." Matching the "quality" of energy provided to the quality of energy required is a central premise of a soft energy path. A soft energy path encompasses more than shifting to the use of renewable energy sources. In soft energy path concepts, energy sources tend

to be more diverse and smaller in scale, matched to local needs and more flexible in responding to changes in the mix of energy required. Soft energy path options, therefore, are less vulnerable to disruption of supply caused by cartels, accidents, or sabotage, and more responsive to changes in demand, due to price changes or government programs.

In soft energy path concepts, large-scale facilities are replaced by smaller facilities that generally are less technologically complex. This scaling down is possible only if the wise use of energy and reduction in energy wastage cumulatively result in a much slower growth in energy demand. Rapid growth in demand favors the economics of large-scale facilities, which are most cost effective if markets for their output develop quickly. Large facilities require seven to ten years from the time of conception until they come on stream. Companies begin to recover their costs only after the facility comes on stream and the product is sold. Changes in demand may make facilities redundant or drastically alter the flow of revenues, making a facility uneconomical. Examples of these changes can be seen in deferred plans for power plants, tar sands plants, and oil and gas exploration activity.

Albertans have used renewable energy sources for hundreds of years, and continue to do so. Early residents preserved meat, fish, and other food through solar energy drying and curing. These residents also used biomass — wood and buffalo chips — to provide heat and energy for other activities. Wood continues to be used as fuel in parts of the province, and many people use solar and wind energy in familiar ways, such as drying clothes. Small windmills were once common in rural areas, as wind energy was used to generate power for the farm or to pump water for domestic and livestock use.

The extensive development of Alberta's non-renewable energy sources — coal in the late 1800s and oil and gas in the early 1900s — soon led to the availability of cheap and convenient alternatives.

Early Energy Crises

The Arab oil embargoes of 1973 and 1979 brought to an end over a century of uninterrupted flow of cheap oil into the world economy. This seemingly endless supply had stimulated economic growth at a pace never seen before and, by the early 1970s, a high rate of growth was assumed to be normal. The events of 1973 changed that and produced a "new" term — energy crisis.

Civilizations have been running out of energy in its many forms for thousands of years. A flourishing copper-smelting industry in Crete literally ran out of wood in the thirteenth century B.C. By the fifth century B.C., forests around the major cities in Greece had been decimated and firewood had to be imported from the Black Sea area, over 600 kilometers away. By the first century A.D., the Romans were importing wood from the Caucasus, over 1,600 kilometers from Rome, and by the fourth century firewood was being imported from France and North Africa. The use of solar energy for space heating was so vital that sun-rights legislation was passed.

However, after the decline of Rome, knowledge of good solar design and the use of specialized products such as glass was lost or suppressed. Wood remained the primary fuel.

The Industrial Revolution spurred a move away from wood. Soon coal was being used in such immense quantities that people worried that it too might run out. Augustin Mouchot, a French mathematician, warned of possible coal shortages in the 1860s and, for over 20 years, investigated solar energy applications. Mouchot is credited with developing the flat-plate collector, the concentrating collector, and other means of converting sunlight into mechanical energy. Other experimenters of the day devised machines that ran on sunlight. Most, however, were defeated by low winter sun angles, poor solar access, and the difficulties of storing energy for use during cloudy periods. Only in remote, arid locations did the use of solar energy flourish. For example, solar water heaters were common in the southwestern United States in the early 1900s, with usage peaking in the early 1920s.

A Revival in Renewable Energy

When the Organization of Petroleum Exporting Countries (OPEC) raised the wellhead price of crude oil from about \$5.00 per barrel to about \$20 per barrel by 1975, it sent shock waves around the world.

Interest in active solar energy and in other renewable energy sources was rejuvenated. It was heightened by price increases that brought oil to almost \$60 per barrel following the commencement of the Iran-Iraq war in 1979. The impact is evident in the following quote:

A National Research Council survey found that in 1977 there were only 15 solar energy systems within a 45-minute drive of Parliament Hill; by the end of 1980, the number was estimated at well over 300 (Schrecker 1983: 16).

However, as the shock of higher energy prices faded, the urgency of finding alternative energy supplies faded. Whether or not there is another energy "crisis," eventually our non-renewable energy sources will be harder to find and develop, prices will increase, and renewable energy sources will become increasingly important.

Chapter Two

Renewable Energy Sources

Solar Energy

The sun has been shining for four billion years, and will last another three to five billion years. It radiates more energy every second than we have used in all our history. The earth intercepts only a tiny fraction of one percent of that energy, yet each day it receives about 500 times as much energy as we use. The amount of solar radiation falling on one square meter of rooftop in most Canadian cities is typically four to five gigajoules (GJ) per year (Schrecker 1983). Expressed another way, three days of average solar radiation on one square meter of surface yields the energy equivalent of one liter of oil. If enough of the solar energy striking the earth could be trapped and controlled, it would supply all of the energy we require. The main challenge is the economic exploitation of a large but dilute energy resource.

Most parts of Alberta are well suited to use solar energy (Fig. 1). The solar energy available during the summer over most of the province compares very favorably with that in other parts of the world and, in fact, southern Alberta has higher levels than any other part of Canada. At high latitudes, low radiation levels in the winter (when the need for heating is greatest) are considered to impose a significant penalty on the use of solar energy, although Segal (1977) argues that the amount of solar energy available to a *fixed flat plate collector* approaches the amount available in the summer. There are two ways to collect solar energy: through active systems or passive systems.

Active Solar Systems

Active solar systems collect solar radiation as either heat energy or electricity. The heat collection systems are usually complex and expensive.

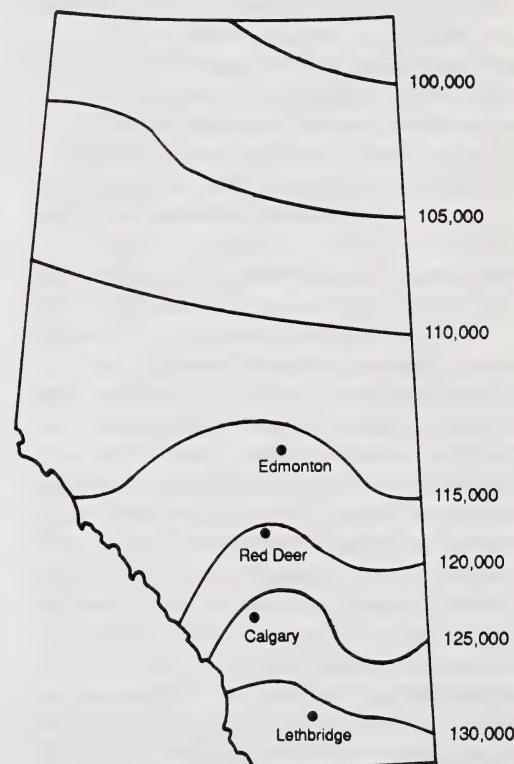


Figure 1. Global Solar Radiation in Alberta

(annual Langleys*)

Source: Nkemdirim 1981

* A Langley is a unit of solar radiation equivalent to one gram calorie per square centimeter of irradiated surface.

Mechanically, they are more sophisticated than passive solar systems, consisting of a collector array, storage tank, and a distribution system. A large expanse of south-facing roof or wall at an appropriate slope must be dedicated to the collector array, and some interior space is required for a heat storage tank. Electricity is required to run pumps and fans. The heat collected may be stored in pools of liquid, in rock or masonry, or in chemical reactions, for later use. Heat is transferred from the storage medium to air or water distribution systems and circulated with fans or pumps. The heat energy collected may be used in a variety of space heating applications. It may also provide low-temperature hot water for industrial or domestic applications or for heating swimming pools.

With cost reductions, it is possible that a viable commercial market for active solar water heating could emerge during the next decade. In seasonal and specialized applications, such as pool heating, active solar collectors are already competitive. In this application, the pool acts as its own heat sink and a minimal heat distribution system is required. With higher conventional energy costs, active solar systems would be attractive for residential hot water, for commercial-scale applications, and, increasingly, for industrial process heat use (Schrecker 1983). At present, most applications of active solar systems are not cost competitive with alternative energy sources. The construction and operating costs are high. Heat storage capacity is expensive and requires considerable space, and in most applications a back-up heating system is required.

In pilot projects, solar radiation has been concentrated with parabolic collectors and focused on a single point to provide extremely high temperatures used to boil fluids, usually water, to produce steam for industrial processes or to drive a turbine to produce electricity.

Solar energy may be converted directly to electricity using photovoltaics, commonly called PVs or solar cells. Solar cells may be made from a variety of semiconducting materials capable of the photovoltaic effect: conversion of light photons into electrical voltage. These cells are wired together in series or parallel to create panels

producing specific voltages and currents. Their efficiency depends on the materials used. The following are theoretical efficiencies for some typical materials (NRCC 1986):

gallium arsenide	24 percent
indium phosphide	23 percent
cadmium telluride	21 percent
silicon	20 percent
gallium phosphide	17 percent
calcium sulfide	16 percent

Actual conversion efficiencies are about one half of the theoretical value. Power is generated for direct use or stored in a battery to be tapped later. These systems need little maintenance and are reliable.

In the early developmental stage are photoelectrochemical cells that convert light into both electrical and chemical energy. These are the equivalent of solar cells that include built-in storage batteries. An advantage is that, during periods of darkness, the electrochemical reaction reverses and generates electricity. The result is that the cell continues to work at an overall efficiency of about 11.3 percent regardless of the light level (*Science News* 1987).

Other advances are being made in thin-film technology, which ultimately may allow sheets of photovoltaic film to be produced. Prices of solar technologies have dropped. According to Best (1988), in the four years from 1984 to 1987, wholesale prices fell 29 percent — from an average of \$7 (US) to \$5 per watt. Bulk purchasers can get modules for \$4 or less per watt. With each drop in prices, new markets emerge and, according to LaPlace (1987), the production of thin film silicon holds substantial promise for future large price reductions.

Solar cells are now common in small electronic applications such as solar-powered calculators. However, for larger applications, PV systems are presently too expensive to compete with the grid system unless the grid is more than a few kilometers away. In remote locations, PV systems can provide cost-effective electricity. Typical installations could supply power for ocean buoys, mountain-top microwave towers, remote

resorts, water pumping, and remote monitoring systems. No power lines or road access would be required. The main disadvantage remains the high cost, and the need for and cost of storage capacity or a back-up power supply during long periods of low solar radiation. Many proponents of PV systems support the concept of a hybrid system for remote applications; the back-up supply would be provided by a diesel generator.

Passive Solar Systems

Passive solar heating systems are frequently considered for residential space heating. Passive systems are less expensive and mechanically less complex than active systems, although a properly designed passive system is very sophisticated. Unlike active solar systems, passive systems collect heat by non-mechanical means. Windows serve as collectors, and internal walls or masonry as the storage system. There usually is no distribution system other than natural circulation, although small fans may be used to move the warm air. Passive systems are particularly well suited to providing low-temperature space heating. Passive solar heating is integral in any energy-efficient house design, and can contribute a high proportion of space heating requirements when energy needs are kept to a minimum.

Passive solar heating has the advantage of low cost in application, operation, and maintenance. There are fewer constraints on building design than with active systems, although a clear southern exposure generally is required. Short days and low incidence of radiation during winter months pose special problems for Alberta, particularly northern Alberta. For these reasons, passive solar systems generally are unable to supply all space heating requirements, especially in energy-inefficient buildings, but when applied in an energy-efficient building, passive solar systems may reduce back-up heating requirements to that of a small electric heater.

Wind Energy

Historically, windmills have been used to grind grain, saw lumber, and pump water, and they were a common sight at one time. Until the late

1940s, many farms were lit by wind-generated power and small, multibladed windmills were used into the 1950s to pump water on prairie farms. More than five million windmills were in use in North America until rural electrification programs provided cheaper, more convenient power. Even today, some farmers still use the old pumperns and, in recent years, there has been renewed interest in wind power.

Today, two basic types of windmills, more properly called wind turbines, are undergoing intensive development. The two types are the horizontal-axis wind turbine, with a propeller-like rotor, and the vertical-axis wind turbine, shaped like a giant egg beater. Most commonly these machines are designed to generate electricity. They are available in a wide range of sizes, from small machines that charge batteries for navigation beacons and telecommunications relay stations, to large units capable of generating several megawatts of power. A well-designed wind turbine with no wind funneling structures can extract a maximum of 40 to 42 percent of the kinetic energy from moving air. Average conversion efficiencies, accounting for operation at other than design wind speed, are typically 30 to 35 percent (NRCC 1986).

The energy produced is strongly dependent on the average wind velocity. Winds in Alberta are variable even in a windy region and their characteristics are a function of local conditions such as terrain (Alberta Energy 1986b). Wind measurements, especially in rough terrain, must be taken with great care. Detailed local measurements of atmospheric conditions would expedite finding and developing suitable sites for wind turbines.

A study using computer modelling and 16 years of hourly wind speed data found that the average potential capacity factor of wind turbines distributed in southern Alberta was approximately 27 percent during times of peak customer electric demand throughout the year. This means that the energy output of an array of wind turbines at locations across southern Alberta would be 27 percent of the maximum possible if the turbines were operating at maximum capacity 24 hours per day (EUPC n.d.). Capacity factors across southern Alberta ranged from 10 to 30 per-

cent (Fig. 2). Average annual operating times ranged from 58 to 80 percent (EUPC n.d.), but installing wind turbines in several locations improves the predictability of electric production. Wind velocities vary among locations and, often, when the wind is blowing at one location, it may not be at another. The EUPC (n.d.) study showed that, theoretically, if wind turbines were operating at three locations in southern Alberta (Pincher Creek, Manyberries, and Suffield) and were taken as a group, then the available operating time (that is, time when at least some power was produced) increased to 97 percent from an average available operating time of 76 percent if each were operating independently.

Because of the high average wind speed, especially in southern Alberta, Alberta now has more than twice the installed wind generating capacity (about 350 kW) of any other province. The cost of wind-generated electric power is now almost comparable to the cost of conventional electricity if the wind turbine can be connected with the electrical grid so the grid system is used for storage. In 1986, six Alberta wind energy producers were connected with TransAlta Utilities. These producers generated 188 megawatt hours (677 GJ) of electricity, of which 48 megawatt hours were purchased by the utility (SOL 1987).

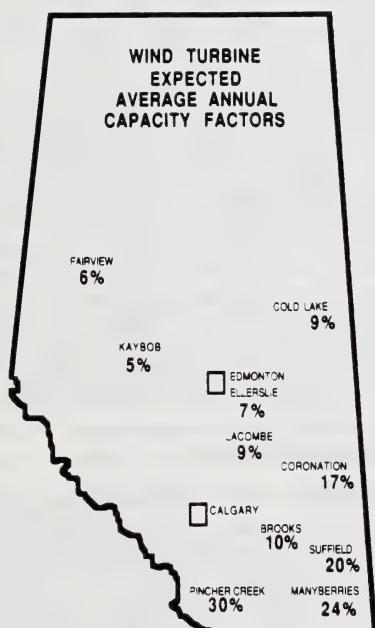


Figure 2a.

Wind turbines installed in southern Alberta would produce more energy per kilowatt of installed capacity than wind turbines installed in central or northern Alberta.

Source: EUPC n.d.

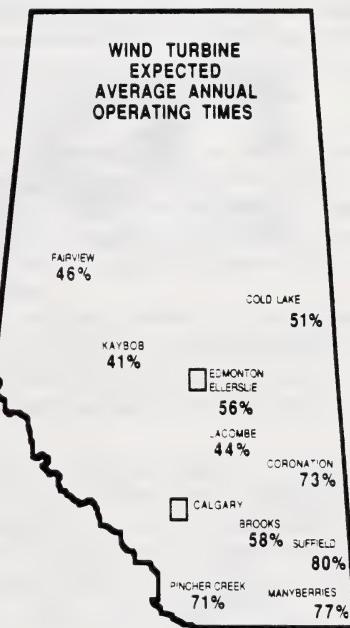


Figure 2b.

Wind turbines installed in southern Alberta would have sufficient wind speeds available to operate more often than wind turbines installed in central or northern Alberta.

Capacity Factor (%) — Energy output of a wind turbine expressed as a percentage of the wind turbine's nameplate rating times total hours available.

Operating Time (%) — Amount of time where sufficient wind speed exists to operate a wind turbine, expressed as a percentage of the total hours available.

Geothermal Energy

"Geothermal" refers to heat from the earth. Ambient temperature increases with increasing depth into the earth. This energy can be tapped in certain regions, usually near fault lines in the earth's crust. Deep wells are drilled to tap pools of hot water or water may be pumped down to dry "hot rock" sources to produce steam or hot water. Depending on the temperature and pressure of the heat sources, geothermal energy may be used to produce hot water or steam. Steam-driven turbines can be used to produce electricity.

The recovery of geothermal energy is not an exotic process that requires considerable research and development work. Systems are already in use in several countries to convert

low-grade geothermal heat into electricity or to use it directly to heat buildings. In 1987, six geothermal plants were operating in the United States, with a combined capacity of about 2,000 megawatts installed in the western states. The Geysers, a dry steam source in California, accounts for about 75 percent of that total (*Groundwater News* 1987).

Scattered areas in the foothills of Alberta with high-temperature thermal gradients could be tapped for energy. As well, the sedimentary basins underlying most of central and southern Alberta have higher-than-normal temperature gradients that permit recovery of water above 50°C. High thermal gradients, about 55°C per kilometer of depth, are found in four general areas of Alberta: Hinton-Edson, Steen River, Fort McMurray, and the northwest corner of the province (Alberta Energy 1986a) (see Fig. 3). These are regions of excellent potential for geothermal heat recovery, depending on the thermal gradient and the reservoir temperature, depth, and volume; rock permeability; and water pumping characteristics. The area around Hinton was investigated further using data from oil and gas drilling records. Recoverable energy was determined to be between 1.8 and 136 megawatts, an amount of energy that could supply the energy needs of 300 to 22,000 homes (Alberta Energy 1986a).

Biomass Energy

Biomass, in the strictest sense, means "that part of a given habitat consisting of living matter." In terms of an energy source, it means plant matter that can be used in its raw form or with modification to produce energy. Various tree species are the most familiar examples. About 0.6 percent of the households in Alberta used wood as the principal heating fuel in 1984, consuming an average of eight tonnes of wood annually (ERCB 1986). Wood also may be used to fuel boilers, to produce steam or to heat drying kilns, as a source of chemicals, or, through processes such as pyrolysis, to produce liquid and gaseous fuels. Other forms of biomass, such as grains, may be used to produce alcohol fuels (methanol and ethanol).

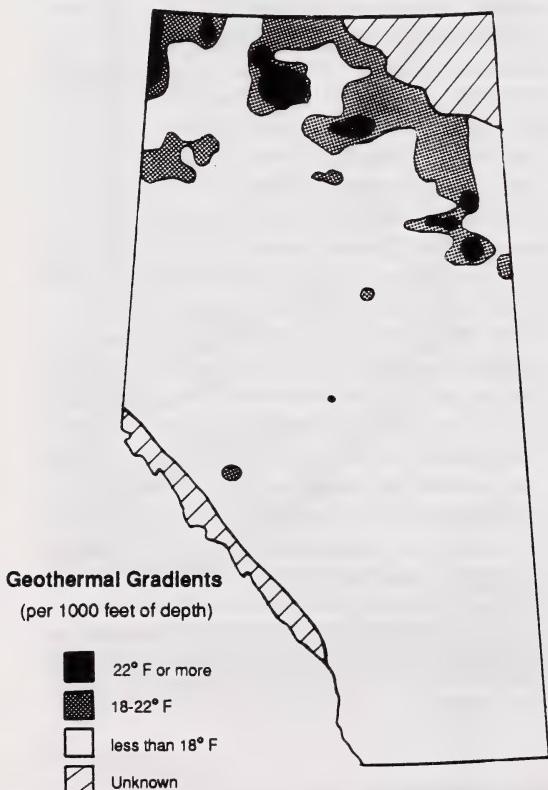


Figure 3. Areas of Highest Geothermal Potential

Source: adapted from Alberta Energy 1986a.

Biomass may also be used in cogeneration facilities, in which both steam and electricity are produced. Simultaneous production of electric power and useful thermal energy converts 80 to 85 percent of the input energy into useful forms.

A recently announced nine-megawatt facility in Ontario will burn 67,000 tonnes of wood waste annually to produce steam and electricity. The steam would be used by a lumber mill and it is expected that 65 gigawatt hours (234 TJ) per year of electricity would be sold to Ontario Hydro (*Energy Analects* 1987).

Large amounts of wood residues — bark, sawdust, chips and shavings — are currently generated by the forest product industry in lumber and pulp mills. Some of these residues, such as chips and shavings produced in lumber mills, are used in the production of pulp or fiberboard products. In fact, in Alberta, the availability of chips and shavings from nearby sources is considered in calculations of the allowable cut for pulp mills — Alberta pulp mills may use up to 50 percent chips as feedstock. Some of the remaining residues, referred to as "hog fuel," are used by the industry to produce steam and heat or, in some cases, electricity.

According to Alberta Forestry, Lands and Wildlife, over 1.6 million oven-dry tonnes of wood waste are generated each year in Alberta. Sixty-one percent is used by industry, but there remain over 630,000 tonnes of wood waste, which are disposed of primarily by burning (ECA 1987). This amount of waste could produce about 12.5 petajoules of energy.

The addition of several new forest industry developments will change these figures, and, as wood utilization standards increase and technologies improve, there will be less wood waste to fuel such facilities. The feasibility of "whole tree" harvesting (removing and using the crown and slash as well as the trunk), utilization of undersized trees in harvested areas, and the harvesting of trees in areas not currently logged has been considered (EMR 1978). The feasibility of biomass plantations that grow woody species as economically viable fuel sources is being investigated at several locations across Canada. Rapidly growing hybrid poplar is often used in these trials.

Other vegetative matter also can be used to produce energy. The feasibility of using peat as a fuel in boilers or in electrical generating plants is being researched in eastern Canada. Studies in Montana are investigating the potential of using leafy spurge, cattails, and "fuel" beets as fuel or to produce fuel alcohol.

Methanol, which can be produced from wood wastes as well as from non-renewable sources, has been used as a fuel or a fuel extender for at least five decades. Most notably, it was used in Germany during World War II when petroleum fuels were extremely scarce. Ethanol produced from sugar cane has been used extensively in automotive fuels in Brazil and other South American countries.

Interest in North America in the use of alcohol as a fuel substitute was high during the late seventies and early eighties. In 1981, Energy, Mines and Resources Canada regarded

methanol from any source, and ethanol from biomass ... as significant medium-term options for Canada which will be technically and economically viable for widespread introduction in the 1990s (as quoted in Schrecker 1983).

However, the recent decline in oil prices has adversely affected the economics of alcohol-gasoline blends. Without government subsidies, these fuels cannot compete with petroleum-based gasoline.

In the United States, about 80 alcohol fuel plants are in production, about one half the number operating in the early 1980s. Nevertheless, "gasohol" sales in the United States still accounted for nearly 8 percent of total gasoline sales in 1986, up slightly from 1985 (*Calgary Herald* 1987a).

In western Canada, Mohawk Oil produces gasohol from low-grade wheat at a seven million liter-per-year plant in Minnedosa, Manitoba. The blend contains 5 percent methanol and 3 percent ethanol and is marketed through Mohawk's gas stations. Mohawk is considering an ethanol plant in Saskatchewan, where a four-cent-per-liter tax break is offered to marketers of gasoline containing 10 percent ethanol made from Saskatchewan

grain. Alberta currently provides a 0.4-cent-per-liter tax break on Mohawk's "EM Unleaded" fuel.

The Government of Alberta is currently studying the fuel ethanol concept with the objective of providing guidelines to direct it in developing related policy. The initial studies indicate that the production of fuel ethanol would require subsidies greater than the benefits to the agriculture industry. These subsidies would have to continue over the long term if ethanol-blended fuels were to continue to play a role in Alberta's transportation fuel needs (Ethanol Fuels Committee 1988; Touche Ross 1988).

A \$100 million ethanol plant is being considered for Dawson Creek, British Columbia. The development of that plant will be assisted by a 40 percent federal investment tax credit, a \$33 million loan from the British Columbia government and a two-cent-per-liter fuel tax reduction for gasohol blends to coincide with the completion of the plant (*Calgary Herald* 1987b).

A plant using 13 to 15 million bushels of barley annually to produce 130 million liters of ethanol each year is proposed for the Lloydminster area. Initially, the ethanol would go mainly to United States markets.

As of December 1, 1987, the use of oxygenated fuels was made mandatory in parts of Colorado during January and February in an attempt to reduce smog. The fuels used include methanol- or ethanol-blended gasolines or ether additives such as MTBE (methyl tertiary butyl ether). These fuels offer benefits in reduced air pollution because they burn more cleanly and produce less carbon monoxide and nitrogen oxides. It is anticipated that carbon monoxide levels in the Denver area will be reduced by up to 10 percent. The use of alcohol fuels, however, may adversely affect the distance driven per liter. As well, there are concerns that alcohol may cause deterioration of some rubber and plastic engine components. Despite these concerns, recent tests have shown that oxygenated fuels work as well as standard fuels and do not damage engines or increase vehicle maintenance (Graf 1988).

Energy from Waste

Traditionally, land application has been the preferred method for disposing of sewage sludge, and in smaller communities it remains the most cost-effective method. Alberta Environment has developed guidelines to permit the application of sludge to land as a fertilizer in an environmentally acceptable manner (Alberta Environment 1983). Larger communities, however, are finding it increasingly difficult to secure sufficient land within a reasonable hauling distance from the sewage treatment plant. In some cases, the elevated level of heavy metals in the sludge has placed severe constraints on its use on agricultural land, because the metals may accumulate in plant tissue and pose potential hazards to animals.

A one-tonne-per-day fuel-from-sewage-sludge pilot plant was recently launched in Hamilton, Ontario to demonstrate and test a technology that converts about 95 percent of the carbon in sewage sludge to usable forms of energy. The process produces 0.3 cubic meters of oil and one half tonne of coal for every tonne of sludge processed, and reduces the volume of sludge by 75 to 80 percent, leaving only an environmentally inert ash. With 500,000 tonnes of sludge being produced annually in Canada, there is potential to recover energy worth \$30 million per year (Environment Canada 1987).

Incineration of municipal wastes also has attracted attention, as the cost of landfilling increases and the public increasingly objects to new landfill sites. For many communities, incineration offers an attractive waste management alternative. Modern incinerators usually recover heat to produce steam or hot water for heating. For example, in Charlottetown, Prince Edward Island, an incinerator burns the city's solid waste and produces steam heat for a nearby hospital. An incinerator planned to handle much of Vancouver's waste will produce steam for a nearby paper recycling mill.

Several communities in Alberta are interested in incineration. One municipal waste incinerator is operating as a pilot project at Wainwright, but it has no heat recovery capability.

The University of Alberta Hospital incinerates its wastes, producing steam for heating and equipment sterilization.

Municipal solid waste also can be used to produce refuse-derived fuel — a processed, burnable fraction of municipal waste. The process,

which usually produces a pelletized fuel, has been tried in Europe and the United States; however, it generally is not economically feasible unless competitive fuels are costly or the process is used to avoid alternative disposal costs.

Chapter Three

Economic Significance

Solar Energy

Active Solar Systems

After the oil embargoes of 1973 and 1979, there was a surge of interest in active solar energy systems. The federal government provided subsidies to purchase and install residential solar water-heating systems for several years in the early 1980s and numerous small businesses sprang up across Canada to install or service these systems. A smaller number of firms started manufacturing systems and components. It is estimated that a typical system could save about one-half of the annual household water heating costs; however, the installed cost is about \$3,000 compared with annual savings of \$75 to \$100.

Many of these businesses have gone bankrupt due to low demand and continuing high prices for active systems, the decline in government subsidies and incentives, and current low energy prices. But in areas where more expensive electricity is the primary fuel, the cost/benefit ratio is better. In 1982, about 1.5 million homes in the United States used solar energy for domestic hot water or pool heating (Blackburn 1987), and the dozen or so Canadian firms that continue to make solar domestic hot water systems sell most of their products to markets outside Canada. In 1985, sales totalled \$15 million with about 50 percent of the production exported, mainly to the southern United States (NRCC 1986).

Electricity generated by photovoltaic devices continues to be very expensive compared to grid power. Only one Canadian company is currently producing its own silicon wafers and manufacturing PV cells and panels. It recently sold a \$3 million PV-manufacturing system to China and

signed a contract worth \$7 million to supply 2,000 PV modules, plus the technology and training for a module production facility in India (SOL 1988). These PV modules are intended to operate PV-powered water pumps.

A few other companies assemble cells into panels in Canada or sell complete systems. Nevertheless, to date, more than 2,000 photovoltaic systems have been sold in Canada and the annual market in Canada is thought to be worth \$3 million, excluding the tiny solar cells on watches, calculators, and other consumer electronics (NRCC 1986).

Passive Solar Systems

According to the National Research Council of Canada (1986), the passive exploitation of solar energy is currently economic in many applications. For example, orienting windows toward the south, reducing heat loss through windows, and other measures can improve the energy performance of a typical house by 20 percent. Significant energy saving also may be realized in commercial buildings. The market for passive solar energy products and information, therefore, promises to be very large.

Wind Energy

The currently installed electrical generating capacity of wind turbines in Canada is about 1.4 megawatts, although the commissioning of other demonstration projects, proposed or underway, could increase this to 10 to 12 megawatts by 1990 (NRCC 1986). In the near future, the best markets for wind energy systems will be in remote communities and industrial sites, where more than 800 diesel generators, with a total power rating of

600 megawatts, now operate. Wind turbines could be cost competitive in some of these locations.

Wind turbine research in Alberta has concentrated on the development of low-speed wind turbines used to pump water in a number of applications, including irrigation systems. Research has been centered at the Lethbridge Wind Research Test Site, where nine wind turbines are currently installed. The wind turbine testing program used is based on international monitoring standards. In 1985, the Lethbridge test site was the only one in Canada to provide internationally accepted performance data.

An export market is seen for wind turbines as inexpensive yet effective water pumps, and Alberta's test site gives Alberta and Canadian manufacturers a competitive edge (Paterson et al. 1985). The technology being developed could be transferred to hydraulic turbines, which could generate power from river, tidal, or ocean currents. Several small power plants using this technology are operating at sites across Canada.

A Calgary firm has developed a huge wind-powered water pumper and is marketing it in Canada and the United States. The use of these water pumps avoids the need for electrical power lines, gas lines, or diesel generators in water pumping applications. In applications remote from these alternatives, wind pumping is an economical alternative.

Geothermal Energy

A study by Alberta Energy (1986a) indicated that the recovery of geothermal energy is possible, and should be practical sometime in the future. However, the economics of recovering thermal energy, including the high capital costs of drilling thermal heat recovery wells, likely will limit recovery to a tiny fraction of the potential. If these costs can be reduced sufficiently, there is a well-established, world-wide base of applications of geothermal energy that could provide useful knowledge to assist the development of Alberta's resources.

Biomass Energy

The prospects for many forms of bioenergy in Canada are favorable. In the forest sector, many companies now treat the decision to purchase systems for recovering energy from forest residues as simply another capital investment decision (NRCC 1986). Biomass energy already supplies half of the forest industry's total energy requirements and proven, commercially available technologies could expand this substantially (Schrecker 1983). The ERCB (1986) is of the opinion that labor and transportation costs relative to conventional energy prices likely will preclude using woody biomass to produce heat, electricity, or liquid fuels on a large scale before 2010, except in the forest products industry.

Liquid fuels, either ethanol or methanol, can be produced from wood, ethanol from hardwoods and methanol from hardwoods or softwoods. The economic viability of this production will depend on sufficient wood supplies within an economic hauling distance, development of markets, and the cost of alternative fuel sources. According to the ERCB (1986), methanol is more likely to be the fuel of the future, although the ethanol process faces fewer technological difficulties. The markets for methanol are more likely to expand rapidly than are those for ethanol. Without expanding markets, large-scale production is unlikely. The economic incentive for the development of technologies, either wood or coal based, for the production of methanol depends on the price and availability of natural gas. The ERCB projection is for no production of methanol from wood and little production of ethanol during the period to 2010 (ERCB 1986). The NRCC (1986) analysis of alternative energy technologies also states that the production of methanol from wood does not appear to be economically viable in the short term, given the huge quantities of natural gas that exist in Canada. It could become economically attractive in the 1990s if natural gas prices increase, but the ERCB (1986) states that unless the feedstock was available as wood waste, the labor and infrastructure required to harvest wood may price the production of methanol out of the market.

A commercial biomass project is proposed for near Athabasca. This project combines a cat-tle-feed and charcoal-manufacturing plant with a five megawatt cogeneration component, all run on locally grown aspen. It is estimated that farmers in the area could make \$300,000 per year selling wood to the plant. In addition, 120 jobs could be created by the operation.

Energy from Waste

In Alberta, low prices for conventional energy and perceived low costs for disposal methods such as landfilling have thus far discouraged development of energy-from-waste plants. Increasing waste management costs and restrictions on landfilling of hazardous waste, however, will increase the incentive to industry, in particular, to consider incineration as a means of waste disposal. If materials can be incinerated to produce heat or electricity for use within the plant, the process offers economic benefits in avoided waste disposal and energy costs.

Interest in incinerating municipal waste also is increasing due to difficulties in finding publicly acceptable landfill sites; however, no serious proposals presently exist. The economic benefits of incineration depend on the nature of the energy recovered (hot water, steam, or electricity) and the markets available for this energy.

Other Considerations

Renewable energy developments (excepting large hydroelectric projects) tend to be smaller, in cost and capacity, than non-renewable energy

developments. This is related to the ubiquitous yet diffuse nature of most renewable energy sources (that is, wind, solar, biomass, energy from waste, and geothermal), but is also a feature of the technology. For example, there is a limit to the practical size of wind turbines, and solar collectors are usually designed as modules. Similarly, because of materials transportation costs, energy from waste and biomass facilities will be relatively small. Renewable energy developments tend to be more numerous, scattered, and diversified than developments based on non-renewable resources. Often they are designed to supply only a proponent's own energy requirements. The significant impacts of renewable energy developments, therefore, are more likely to be economic than environmental, as large-scale, capital-intensive projects are replaced by scattered, smaller projects.

A levelling off of demand for energy favors a shift from large, capital-intensive projects to smaller, usually more labor-intensive projects. Industry, planners, and society as a whole will be forced to adjust. Adjustments already are evident in the postponement of thermal power plant development, the failure of anticipated (in the late 1970s) tar sands developments to occur, and the indefinite delay in planning for a Slave River dam. Instead, industries are incrementally expanding tar sands plants and heavy oil developments, and renewable energy projects, such as wind turbines, biomass-powered generating stations, and ethanol-from-grain plants are being proposed or constructed.

Chapter Four

Demand Projections

Projecting energy requirements and the proportion that renewable energy sources will supply is an unenviable task that faces those planning energy supply systems or developing markets. In the not-too-distant past, projections were made by extrapolating past growth in energy use. Forecasting is now assisted by computer models that take into account a wide variety of factors. Nevertheless, despite the apparent sophistication of forecasting techniques, projections depend on assumptions and are not a guarantee of future demand.

Events of the last decade have shown dramatically the fallibility of forecasting. Higher energy prices affected all areas of economic growth and the energy use which that growth generated. In a very short time, energy forecasts changed markedly. For example, in 1981 electricity demand in Alberta was predicted to increase from 3.7 gigawatts to about 6.1 gigawatts by 1986. In actuality, it increased to less than 5.2 gigawatts. The result was a delay in construction

of the Genesee, Keephills, and Sheerness power plants and an indefinite delay in planning for a dam on the Slave River. Similarly, projections of demand have decreased for other energy sources: coal, oil, and natural gas.

The slow-down in the economy has not been the sole factor affecting energy demand projections, although it has been significant. There also have been significant improvements in the efficiency of energy use. Developments in energy conservation, insulation, downsizing of automobiles, improved engine efficiency for all modes of transportation, improved furnace efficiencies, and modification to industrial processes all have contributed to the end result: less energy is required to do more. Between 1973 and 1986, energy use per unit of production dropped about 14 percent (EMR 1987).

Moreover, according to Ross et al. (1985), this trend is likely to continue. Even with substantial growth in Alberta's economy, they predict no increase in overall energy use to the year 2010.

Forecasts by Alberta's Energy Resources Conservation Board to the year 2010 are at odds with these projections (ERCB 1986). The ERCB predicted that, although residential, commercial, and transportation energy requirements will increase only slightly between 1985 and 2010, industrial and primary energy requirements will increase substantially, due mainly to oilsands development (ERCB 1986) (see Fig. 4).

Slower growth in energy demand, coupled with higher prices for energy, provides the opportunity to gradually shift from non-renewable to renewable sources of energy and to incorporate

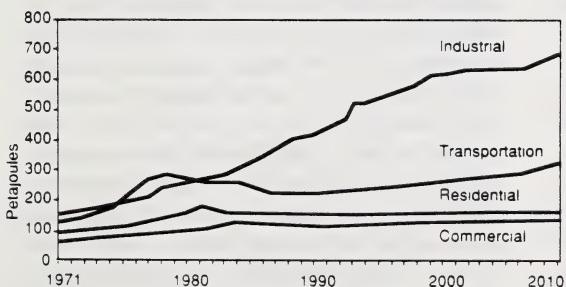


Figure 4. Secondary Energy Requirements by Sector

Source: ERCB 1986

new, more efficient technology in all sectors of the economy. How much of Alberta's energy requirements will be supplied by renewables at a lower cost than by non-renewables? The study by Ross et al. (1985) provides some suggestions. That study differs from most traditional energy studies for Alberta in four ways:

- energy conservation is seen as "the logical first place to focus attention" because it "will increasingly predominate energy planning as all sectors of society attempt to reduce operating costs" (page 2).
- concern is shown "not only for the quantity of energy but also for its quality" (page 3).
- environmental constraints and concerns are considered, including "nuclear power (precluded), limits on large scale hydro development (Slave River development rejected), concerns for atmospheric emissions, biomass considerations (promote renewable energy but exclude wildlife areas as a source for wood) and demand reductions" (page 3).

- it assumes that energy prices in the province will move toward reflecting full production costs rather than the subsidized costs paid today.

The study examined energy use by sector and fuel type. Under the conditions of their main conclusion, that our ability to use energy more efficiently means that "the Alberta economy could grow substantially with no increase in energy use to the year 2010" (Ross et al. 1985: 67), renewable energy sources slowly replace some non-renewable energy sources, primarily liquid fuels. The report further states that adequate resources are available, and that many renewables, such as biomass plants, could be phased in more rapidly and at a lower cost than petroleum-based alternatives, although "the total secondary biomass energy (solids and liquids) comes to less than one half of the output of a single full scale oil sands plant." (Ross et al. 1985: 68). The completion of the shift from conventional fuels to renewables was not expected to be complete until about the year 2025.

Chapter Five

Achieving Sustainable Use

Alberta is in the enviable position of having abundant renewable and non-renewable energy sources to fuel its industry and support its population. Over the next several decades, the main concern in energy management will not be energy shortages, but the province's ability to shift, with minimal economic, environmental, and social disruption, among different energy sources as some sources become less abundant and more costly. In managing these shifts, it is important to consider not only the relative abundance of replacement energy sources, but also the short- and long-term economic, environmental, and social costs of developing alternative sources.

The success that renewable energy sources could have in meeting future energy demands is inexorably tied to improvements in energy use efficiencies and reduced rates of growth in demand for energy, because renewable energy sources tend to be dispersed and not suited for "megascene" developments that are needed to meet rapid increases in demand for energy. The trend toward more efficient use of energy is already well underway and is clearly influencing demand trends. Slower growth in demand for energy lengthens planning horizons, reduces the consequences of mistakes in demand forecasts and eases the transition from one fuel source to another. Under these conditions, development of renewable energy options becomes more practical. For example, it is nearly impossible for passive solar heating to make a cost-effective contribution to the energy requirements of an inefficient house in which it might provide 20 percent of the heating requirements. If the overall heating requirements were reduced by 70 percent through conservation techniques, the same passive solar system would

provide two-thirds of heating requirements and become a cost-effective and practical supplement to the present fuel source.

High rates of growth in energy demand favor large-scale projects that increase energy supplies in large blocks. For example, 350 to 500 megawatts is the capacity of a single unit in a coal-fired power plant; a large tarsands plant such as Syncrude could produce 20,000 cubic meters of crude oil per day. The cost of increasing capacity cannot be recovered until the energy is marketed. Additions in energy capacity of this magnitude are most economic when growth in demand is high and rapidly provides markets for the large block of new energy production. As energy requirements are reduced and as growth in demand for energy lessens, it becomes technologically more feasible and economically more viable to meet the incremental energy requirements using a renewable source of energy. If the growth in electrical demand was 100 megawatts per year instead of 300 megawatts per year, as it was between 1981 and 1986, incremental increases in production of 350 to 500 megawatts likely would be too large to be economical and alternatives would have to be found.

The previous section provided a brief overview of future energy demands. Can renewable energy sources supply these demands? To answer this question, it is useful to look at the quality of energy required and the sources of renewable energy that might meet these needs. Energy requirements can be broken down into four general categories: low-temperature space heating, industrial process heat (both low temperature and high temperature), liquid transportation fuels, and electricity. An important factor in achieving sustainable use is the match-

ing of the quality of energy available to the energy needs. Breaking down the energy requirements on the basis of end use of the energy is one way to encourage matching of energy needs and energy sources.

Low-Temperature Space Heating

The use of renewable energy sources for low-temperature space heating has been widely promoted, especially for residential heating. Passive solar systems could supply much of the heat needed by well-designed, energy-efficient homes. Commercial buildings of the future likewise could draw substantially on passive solar heating to supply winter heating needs.

Geothermal energy recovered with heat-pumps could provide space heating. Of the four areas in the province with high-grade geothermal energy potential, two are far from population centers and one has limited potential for recovering the energy. However, the high temperature gradients found in the Hinton-Edson area could generate heat for between 300 and 22,000 homes, or provide energy to local industries. A normal-gradient area near Calgary has potential to supply usable energy to that city. While these projects are not currently economically feasible, the situation could change if conventional fuel prices were to increase.

Burning wood for space heating is most practical in northern Alberta, where wood is readily and inexpensively available. If wood is to be used as a fuel in densely populated areas, air pollution controls on wood-burning appliances must be greatly improved. Oregon probably has the best emission standards for woodstoves in North America, and these could be used as a starting point. Standards should be firmly in place, and better quality stoves widely available, before we attempt to increase the use of wood as a space-heating fuel.

Many pulp mills use wood waste to provide heat for the mill complex. Heat might be produced for residential use. Getting the heat to a large number of buildings would involve a huge initial capital expense, and would be impractical in an existing built-up area. Running underground hot

water lines would be easier in a new subdivision or a new industrial park; however, district heating schemes often are uneconomical for energy-efficient buildings. Similarly, the use of "waste" heat from the incineration of municipal waste for industrial or district heating should be carefully explored. The challenge is co-ordinating the available resources and the development constraints before the plans are drawn up and work commences.

Many renewable energy sources could be used to supply low-temperature heat for residential, office, and commercial space. Some of these are economically feasible at present, especially when new buildings are designed with energy conservation and renewable energy sources in mind. Other sources, such as wood heating, may be impractical for heating in urban areas because of concerns about air pollution.

Industrial Process Heat

Industrial processes usually require more heat and hotter temperatures than space heating. Passive solar systems usually are not able to supply energy of this quality. Although active solar systems may meet these requirements, current economics have limited their use to a few applications such as preheating of water. Geothermal heat sources in Alberta suffer from similar economic difficulties and likely would require some form of supplemental energy to satisfy all of the process heat requirements.

The area of greatest potential for contribution by renewable energy sources is in the use of biomass and energy from waste. As mentioned earlier, the forest industry already uses a considerable amount of its wood waste to produce heat or steam. Incineration of municipal waste is used in several locations in Canada to produce steam for heating or industrial use.

Liquid Fuels

For the foreseeable future, transportation fuel requirements will continue to be dominated by liquid fuels. Although electrically powered vehicles are technically feasible, there are significant dif-

ficulties to overcome, related to economics and distance travelled between battery charges, before they become a practical alternative.

Few renewable energy sources conveniently produce liquid fuels. Among them, biomass conversion has potential to produce methanol or ethanol as a replacement fuel or as an extender of refined petroleum products. Biomass conversion currently is marginally economical. With rising energy prices, it will become more attractive as a source of liquid fuels.

Electricity

Electricity is predicted to grow in importance as the form of energy in use (EMR 1987; Ross et al. 1985), displacing oil and natural gas in some uses, and supplying projected increases in use in appliances, lighting, office use, and so on. Several renewable energy options produce electricity. Photovoltaic cells are currently economically attractive in locations without access to a grid system. With cost reductions, improvements in battery storage systems, and increased radiation capture efficiencies, as well as increases in the price of alternatives, solar cells may be able to supply a larger portion of the electricity required to serve the summer-time needs of small, more remote communities or to replace diesel pumps or generators.

Wind turbines could meet some of the electrical demand or replace electrical or diesel water pumps.

Electricity could be generated by burning waste materials or wood. Biomass conversion to electricity currently is a viable option where it also offers the benefit of waste disposal, or where the "fuel," such as wood waste, is available at no cost.

In summary, some form of renewable energy is available to supply energy at all levels of "quality" required: heat, liquid fuels, or electricity. Several sources are already economically viable alternatives in certain circumstances. More research will undoubtedly advance technology and reduce costs, making more applications of renewable energy viable.

Under a scenario of reduced growth in energy demands and increasing energy prices, the portion of the energy requirements supplied by renewable sources should increase. The increased use of renewable energy sources, coupled with a reduction in overall energy demand, should give Alberta time to take the steps necessary to make a smooth transition to a future much less dependent on non-renewable resources. The challenge is to determine the appropriate strategies to encourage the development of renewable energy sources while optimizing the benefits of Alberta's non-renewable resources.

Interactions With Competing Users For The Same Resource

There may well be limits to the capacity of the natural environment to absorb discharges of heat [and carbon dioxide] that result from continually increasing use of conventional fossil fuels and nuclear energy. A number of renewable energy sources, notably solar, wind, tidal and hydroelectricity, would not add to these total discharges in a global context, though they may still concentrate heat release in certain geographic areas. (EMR 1976: 104).

Renewable forms of energy are generally regarded as being intrinsically less environmentally damaging than the more conventional higher technology energy systems, although most forms of renewables are not environmentally neutral. For example, development of biomass plantations could cause land use conflicts. Energy-from-waste projects can produce usable heat, significantly reduce the volume of municipal waste being landfilled, and indirectly reduce risk of water contamination by leachates from these landfills. This reduction may be at the expense of an increase in undesirable air emissions and the release of highly toxic organic compounds such as dioxins, unless these substances are deliberately controlled, at some economic cost.

Solar Energy

There are essentially no competitors for the main component of any solar energy system — sunlight. The only time a conflict occurs is when a solar collector or PV system is being shaded. This can be remedied by proper placement of the solar collectors, or by regulating the height of new buildings to the south of solar collector arrays. New solar

buildings in a built-up area might have problems. Urban planners might begin now to plan new housing development and commercial business areas so that buildings are oriented to make most efficient use of available radiation and are protected from shading.

Large areas of land would be required if PV installations were ever to supply a significant percentage of Alberta's electricity requirements, but it is a much smaller area than one might expect. According to calculations done by Pulfrey (1977), an area of at least 10 square kilometers of collectors is necessary to support a power facility with a peak rating of 2,500 megawatts. In 1986, the generating capacity in Alberta was about 6700 megawatts (ERCB 1986). To replace this capacity with solar cells would require about 30 square kilometers of PV cells. This is a small fraction of the 660,411 square kilometers contained in Alberta.

These numbers are presented only to illustrate the potential of solar energy. It is unlikely, and maybe even undesirable, that PV cells would be used in utility-sized power generating facilities. One of the main features of many renewable energy alternatives is their ability to supply energy at a local level suited to local needs. These benefits are lost with utility-sized facilities. It may be more attractive to consider thousands of smaller facilities supplying the needs of homes and communities, with backup power supplied by batteries or diesel-powered generators. In this way the high cost and land requirements of power transmission could be minimized. Properly planned, designed, and located solar arrays could be placed on marginal lands for larger applica-

tions or on roof tops for smaller applications. The impacts of such projects would have to be weighed against the land use impacts of alternative energy developments such as coal mines for thermal power plants and hydroelectric dams and reservoirs.

Wind Energy

Some wind farms in the United States have had problems with neighbors complaining about the noise of the turbine blades swishing in the wind. This is likely to be less of a problem in Alberta because of lower populations. Wind farms could potentially become tourist attractions by providing visitor facilities and information. Development of wind farms could conflict with other land uses, such as agriculture.

Where smaller windmills are used for specific, individual applications, these concerns will be minimized. Windmills designed to pump water are one such application. If alternative power supplies are avoided in these site-specific applications, linear disturbances for power lines or fuel supply lines would be eliminated.

Geothermal Energy

The development of geothermal energy potential in Alberta is hindered by the high cost of drilling wells. Fortunately, Alberta has been able to obtain good information about its geothermal energy resources from data collected during the logging of oil and gas wells. This information, more than 55,000 bottom hole temperature values, was the basis for mapping Alberta's geothermal potential (Alberta Energy 1986a). These same drill holes might be used for the recovery of geothermal energy if they were non-productive for oil or gas. Unfortunately, current practice is to plug unproductive holes with cement. This renders them useless for water extraction. If oil and gas companies could be convinced, when drilling wells in areas of high thermal gradients, to consider the possibility that a non-productive well might be used to recover geothermal energy, the high capital cost of drilling wells specifically for the development of geothermal

resources could be avoided (Alberta Energy 1986a).

Geothermal developments also pose environmental problems related to the disposal of the brine that would be produced. This brine might be used to enhance oil recovery in nearby oil wells. Other impacts would be the need for road access, and disturbances caused by site preparation, power lines, hot water or steam pipelines, and other associated developments. These impacts would be similar to those associated with the development of alternative energy sources such as oil and gas. It is difficult to predict the net impact.

Biomass Energy

The use of biomass to produce liquid or solid fuels was identified as having substantial growth potential in the near term (Ross et al. 1985). Much of this fuel might be used in industrial cogeneration facilities. Some would be waste material, mainly wood wastes. As well, some biomass could be harvested specifically as a fuel source.

In Alberta, forest biomass offers substantial potential as an alternate energy source, if concerns about the long-term sustainability of the forest ecosystem are addressed. Management of a forest area as a biomass plantation could produce a very different "forest" than we now know, although the area affected likely would be relatively small. According to Ross et al. (1985), five percent of the area under timber management agreements in 1985 would supply the biomass requirements projected to the year 2010. In mixed stands, the softwood trees could be removed for lumber production and the hardwoods removed for biomass fuel production. Restocking with softwoods could increase timber production.

In many areas of the province, the demand for hardwood has increased dramatically as plants are proposed or operating that use the hardwoods for press board, oriented strand board, pulp, or cattle feed. This increased interest in using hardwoods is the result of changes in markets, but also reflects changes in utilization standards for these woods in mixed wood stands. The availability of wood and the economics of

biomass conversion depend largely on the growth in demand for hardwoods and future changes in utilization standards for harvesting operations. Increasing demand from the variety of users will create more interaction and make it increasingly difficult to satisfy all demands on the forest resource.

Converting agricultural wastes to energy may reduce agricultural waste management problems; however, these "wastes" (straw, manure, etc.) are important in maintaining the fertility and tilth of soils. Cultivating land, especially marginal land, to produce biomass fuels may have negative impacts on soil quality, increase erosion and stream siltation, and speed the loss of wildlife habitat. However, the use of crop surpluses offers attractive benefits in diversifying

agricultural markets and providing new industrial opportunities in rural areas.

Energy From Waste

The use of municipal waste as fuel helps address concerns about landfilling of waste, but, in turn, likely will face opposition related to environmental consequences of incineration, even though emissions from a properly designed and operated incinerator meet existing emission guidelines and regulations. Urban planners will be faced with the difficult task of finding acceptable sites. Locating such facilities in rural areas will likely produce conflicts with agricultural activities and rural lifestyles, as well as increasing transportation distances and associated energy requirements.

Legislative And Regulatory Regime

Alberta has little legislation that directly affects the development and use of most renewable energy sources. Several legislative requirements, however, indirectly affect renewable energy developments. For example, housing construction must meet building codes. Because of the "assembly line" approach taken to design and construction of residential dwellings, the application of this code, although not directly affecting the use of solar technologies, may constrain innovative thinking and the incorporation of active or passive solar systems in building design.

There are few regulatory constraints on the use of wind turbines. Although the use of wind turbines in residential areas likely would be restricted by bylaws because of visual impacts and possibly noise concerns, it is unlikely that wind turbines will become a practical means of providing energy for residential use.

A more significant problem is the lack of fully developed policy concerning the connection of wind turbines and other renewable energy generators to the electrical grid. Recent Energy Resources Conservation Board (ERCB) hearings on the pricing of energy from "small power producers" and their connection with Alberta's grid system are a part of the formulation of such policy. In July, 1988, the Government of Alberta passed The Small Power Research and Development Act, which allows producers of electrical power from wind, biomass, or hydro at small facilities (those with a nameplate capacity of not more than 2.5 megawatts) to sell power to the electrical utilities at a contract price of 5.2 cents per kilowatt hour for the duration of the contract. Such facilities would not be subject to ERCB hearings concerning whether the facility is an economic source of

electricity or whether there is a need for such a facility in meeting Alberta's electrical energy requirements. The Act applies to a maximum addition of 125 megawatts of generating capacity in small power projects. As well, provision is made for pilot projects with a capacity greater than 2.5 megawatts, subject to regulations.

Larger renewable energy projects would require ERCB approval on need and economic rationale. All projects require local development approvals in the same manner as any industrial development.

Regulations for geothermal developments are not clearly developed. Water well drilling companies are required to file reports on any holes drilled. But geothermal wells would be considerably deeper and probably would require permits from the ERCB, as do all wells deeper than 500 feet. Geothermal wells may also require Clean Water Act licenses related to the disposal of brine. Local development permits would be required.

Energy from waste and biomass operations could require licenses under both the Clean Air Act and the Clean Water Act of Alberta. ERCB approval could also be required if the facilities produce marketable products. According to information received by the Environment Council of Alberta during its inquiry on recycling, even if materials are incinerated to produce electricity for use within the plant or institution, written approval must be obtained from the electric utilities (ECA 1987).

As renewable energy is developed further, especially commercial developments, government policy and regulatory regime will have to be clarified. This process is underway, but there is a long way to go before there is a clear direction from government on renewable energy development.

Policy Formulation

In the absence of clear direction from government, renewable energy development is affected mainly by economics and by the indirect impacts of policies aimed at other energy sources.

Many alternatives could be pursued to move society toward greater use of renewable energy sources. Among these are legislative, administrative, and accounting changes to account for and internalize all costs when pricing energy alternatives; policies to encourage market-like responses when these are not readily forthcoming; and financing of research and development. Much of the following is based on *Soft is Hard* (Elder n.d.) which presents a detailed discussion of the barriers and incentives for both "hard" and "soft" energy sources.

Supporters of renewable energy development point out the discriminatory financial treatment of non-renewable energy sources. Exploration for oil and gas is subsidized by generous income tax deductions; financial incentives; and government grants, loans, loan guarantees, or equity purchase. Renewable sources appear less cost competitive by comparison.

Economic barriers can be removed by:

- eliminating price control on non-renewables where this still exists
- eliminating tax treatments that favor non-renewables
- altering tax investment credits to be consistent for all energy sources
- providing accelerated depreciation for development of renewable energy sources.

However, even in a free market system, the price of energy supplies may not truly reflect the

full "social costs" of development. These full costs include the long-term marginal cost of increasing supply and the cost of minimizing the externalities. Pollution control is commonly used to illustrate internalization of cost. For example, in the case of acid rain, or the increase in atmospheric carbon dioxide, the finger of blame is pointed at the burning of fossil fuels as the cause. Burning these fuels imposes a cost in the form of degradation of the environment — a cost that is borne by the whole of society and thus is external to the normal accounting process. If pollution controls were imposed to reduce the impacts on the environment, more of the costs would be borne by the direct and indirect beneficiaries of fossil fuel use. The costs then are said to have been internalized.

The assumption is that many forms of renewable energy impose less external cost than non-renewable energy sources and, if all costs of energy use were internalized, then renewable energy sources would become more cost competitive with many of the non-renewable sources. The generalization may not apply to all sources, but certainly some renewable energy sources, for example, passive solar and wind energy, seem to be more environmentally benign than some non-renewable energy sources.

But we don't know the full costs of our present energy production and, until we do, it is difficult to recognize the complete value and place of the alternatives. LaPlace (1987) calls for efforts to be undertaken to identify the real costs of energy supply in Canada. Passmore and Associates Limited (1987) suggest a public inquiry in each province to determine the costs of new electrical generation facilities, as a first step toward permit-

ting private power options to flourish as an alternative to public utilities.

Until energy pricing in the marketplace is changed to account for the social costs as well as the full financial costs, according to Elder (n.d.), market forces alone may not produce society's desired goal for renewable energy development. As well, market forces may act more slowly than is desired because of inertia in the system related to replacement of existing, less energy efficient appliances, motors, housing, and so on.

For example, although the operating costs or the lifecycle costs of renewable energy alternatives may be competitive, the capital cost of replacing existing sources of energy may be a significant barrier. Thus, gas-fired boilers may not be replaced with biomass burners, propane-powered cars do not readily replace gasoline-fueled ones, and the capital costs of supplementing grid electricity with a wind turbine are beyond the reach of all but the most visionary. When replacements are needed, however, the alternatives may seem feasible.

It may be desirable to use incentives to encourage a more rapid replacement of inefficient or inappropriate technology, or to bring in standards or regulations that speed up the conversion.

Both actions have been used in Canada. For example, the federal government offered grants and rebates for insulation improvements and to encourage a shift from oil heating to other sources of home heat. Car manufacturers are required to improve car fleet efficiencies. Similar initiatives could be used to speed the normal rate of shifts in energy use in the face of a future of rising energy prices.

Other economic barriers include difficulties in obtaining financing for new technologies until they are proven, insurance problems of various sorts, and the difficulty of specifying design and operating costs for renewable energy sources like solar, wind, and biomass that depend on site-specific and often uncontrollable variables.

However, as Elder (n.d.) points out, it does not automatically follow that renewable energy should receive the same level of support as other energy sources, or that they should all receive none. Different technologies may need different

levels of funding, and a technology may need different funding depending on its stage of development — research, technology improvements, or marketing. The scientific problems of extracting energy from renewable sources may be such that the present level of funding for research is inadequate.

Tax benefits or incentives also may differ for different energy sources. One factor to consider is the overall social costs. If these are included in the equation, then support can be provided at a level proportionate to the overall social benefit. Perhaps it is preferable to support methanol development from biomass as compared to coal. Proponents of renewable energy developments argue that the social costs of these developments generally are much less than those of non-renewable developments and hence renewable energy should be treated favorably.

The Friends of the Earth (1983) also call for energy prices that reflect the real cost of supplying energy. Investment then would be redirected toward energy productivity rather than energy supply development, because increased energy efficiency requires less capital than does increased energy supply. In the same vein, Ontario Hydro is reported to be planning to offer its major industrial customers grants and low-interest loans to reduce their electricity consumption (*Globe and Mail* 1988).

Policies and programs with the best chance of success are congruent with the attitudes and values of the citizens. Energy conservation assistance programs were very successful. Programs in eastern Canada that encouraged industries to shift away from oil as a fuel have been successful because they responded to industry's concern about the long-term outlook for oil prices and supply. On the other hand, attempts to encourage active solar systems met with only qualified success because of user concerns about aspects such as the technology, maintenance, long-term costs, and lack of proven applications.

Both the private and public sector may be biased against some renewable energy sources. The use of renewable energy sources may be seen to mean a lifestyle change, and resulting social change. There is an inertia in the present institu-

tional and financial structures that will resist such change. The economic system is growth oriented and seems inclined toward megaprojects. Megaprojects or conventional energy developments may be perceived to create more employment than renewable energy developments, which often are smaller and designed to meet local needs. In general, however, renewable energy projects tend to be more labor intensive and less capital intensive.

Changes in the status quo will be opposed by many sectors, including most of those that have a stake in present energy developments. Concerns about changes in employment qualifications, numbers, and locations can be expected from labor representatives.

As Lovins et al. (1981) point out, most analysts find it unfamiliar, and therefore difficult, to consider the possibility of meeting the energy needs of a major industrial nation with a large number of diverse, and often dispersed and relatively small sources. It is therefore common to dismiss as too small the contribution of any particular one of a myriad of renewable sources, or to fault it for its shortcomings if it is used to try to imitate the style or scale of conventional centralized systems.

There are also questions regarding the comparative environmental trade-offs of renewable and non-renewable developments. Often there is not enough information about the availability and performance of renewable technologies to endorse

specific technologies. For example, what are the implications of biomass plantations, energy from waste, geothermal energy developments, or the manufacture of PV systems?

Individuals and companies may be hampered by the lack of information from making a commitment to a new technology. Are replacement parts and service available; what performance can be expected; is there a guarantee? Should purchases be postponed because technological or cost breakthroughs are imminent?

According to Elder (n.d.), the ultimate criterion for deciding on change is: will this policy help or hinder the appropriate evolution of society? If we decide that a change toward greater use of renewable energy should be encouraged, then policies should be implemented with minimum effort and expenditure, using existing institutions. Among the steps that might be taken are to remove undesired incentives or barriers; ensure that government purchasing policies reflect the desire to favor certain technologies; undertake information, education, and training programs; implement economic disincentives to discourage "inappropriate" energy use; set standards that encourage renewable energy development; and establish economic incentive programs.

These are only some of the many avenues open to encourage more rapid development and implementation of renewable energy alternatives.

Chapter Nine

Conclusion

Alberta has been blessed with an abundance of both renewable and non-renewable energy. In recent decades, the availability of fossil fuels has been an important driving force behind economic growth in the province and the export of fuels and products manufactured from fossil fuels has brought the province significant revenues.

But fossil fuels are becoming less readily available, and more costly to develop. Increases in energy prices have affected all areas of economic growth as well as the energy use which that growth generated. The last decade has seen rapid, unexpected technological improvements in energy efficiencies, conservation, alternative energy sources, and recovery technology for non-renewable energy sources. Energy forecasts have changed markedly, as has our attitude toward energy use. Furthermore, most of these changes have been accomplished with little noticeable change in lifestyles or standard of living.

Alberta has a range of renewable energy sources that could be called upon to meet future energy requirements. Some areas of Alberta receive the highest annual incidence of solar radiation in Canada, others have average wind speeds very favorable for the operation of wind turbines. Much of Alberta is forested, and existing or proposed projects provide significant opportunities for biomass developments using wood wastes or currently undesirable tree species. In other areas, biomass plantations may be feasible.

Agricultural products or wastes provide another source of large quantities of biomass suited for the production of alcohol fuels. Alberta also has areas suitable for tapping geothermal energy sources.

Over the next several decades, the main concern in energy management in Alberta will not be the availability of sufficient energy. Renewable sources are available to supply energy in most forms required and several sources are already economically viable alternatives. The main issue will be society's choice of energy sources and the province's ability to shift, with minimal economic, environmental, and social disruption, among different energy sources as some sources become less abundant and more costly.

Energy forecasts provide projections of future energy use and sources of supply based on trends and assumed impacts of factors such as changes in the value of energy. These trends indicate a gradual replacement of non-renewable energy sources with renewable energy. Is the transition occurring fast enough? Should specific actions be taken to influence the change? In fact, what kind of energy future do Albertans want?

Albertans have an opportunity to decide now what their energy future should be, and the role of renewable energy sources in this future. A framework will be required within which to make these decisions. The Alberta Conservation Strategy provides this framework.

References

- Alberta Energy. 1986a. *Geothermal Energy Resources in Alberta*. Alberta Department of Energy.
- _____. 1986b. *Measuring and Harnessing Alberta's Wind Resources*. Alberta Department of Energy.
- Alberta Environment. 1983. *Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands in Alberta*. Prepared by: D. McCoy, D. Spink, J. Fujikawa, H. Regier, and D. Graveland. Standards and Approvals Division and Earth Sciences Division, Alberta Department of Environment.
- Best, D. 1988. "Solar Cells: Still a Tough Sell." *Sierra* 73(3):27-29.
- Blackburn, J.O. 1987. *The Renewable Energy Alternative: How the United States and the World Can Prosper Without Nuclear Energy or Coal*. Durham: Duke University Press.
- Calgary Herald*. 1987a. June 29, page E5.
- _____. 1987b. July 11.
- Elder, P.S. 1984. *Soft is Hard: Barriers and Incentives in Canadian Energy Policy*. Detseig Enterprises Limited, Calgary.
- Electric Utility Planning Council (EUPC). n.d. "The Availability of Wind Resources to Meet Alberta's Electric Demand." Brochure. EUPC.
- _____. 1986. *EUPC Forecasts of Alberta's Electric Energy Requirements 1986 to 2010*. EUPC.
- Energy Analects*. 1987. "Ontario Cogeneration Facility to Sell Steam Heat, Electricity." 16(October 5):5-6.
- Energy, Mines and Resources Canada (EMR). 1976. *An Energy Strategy for Canada: Policies for Self-Reliance*. Energy, Mines and Resources Canada.
- _____. 1978. *Tree Power: An Assessment of the Energy Potential of Forest Biomass in Canada*. Report ER78-1. Energy, Mines and Resources Canada.
- _____. 1987. *Energy in Canada: A Background Paper*. Energy, Mines and Resources Canada.
- Energy Resources Conservation Board (ERCB). 1986. *Energy Requirements in Alberta*. Report No. 86-A. ERCB, Calgary.
- Environment Canada. 1987. "Turning Sludge into Energy." *Environment Update* 7(1):14.
- Environment Council of Alberta (ECA). 1987. *Recycling Waste in Alberta: Technical Report and Recommendations*. ECA, Edmonton.
- Ethanol Fuels Committee. 1988. *Ethanol Fuels for Alberta: A Discussion Paper*. Alberta Department of Agriculture.
- Friends of the Earth. 1983. 2025: *Soft Energy Futures for Canada*. Vol. X. *A Soft Energy Path for Alberta*. Prepared as part of the Friends of the Earth Soft Energy Path Study for Canada. Energy, Mines and Resources Canada.
- Globe and Mail*. 1988. "Ontario Hydro Tries No-Growth Options." Report on Business section. February 1.
- Graf, T. 1988. "Front Ranges Breathe Easier." *Sierra* 73(2):27-28.
- Groundwater News*. 1987. "Largest Binary Geothermal Plant to Shut Down for a While." 16(13):6.
- LaPlace, R.L. 1987. "Photovoltaics: A Place in Canada's Energy Future." Paper presented at *Energy Options — Meeting Canada's Energy Needs*. Dec. 7-9, 1987, Montreal, Quebec.
- Lovins, B.A., M.A. Lovins, F. Krause, and W. Bach. 1981. *Least-Cost Energy: Solving the CO₂ Problem*. Andover, Mass.: Brick House Publishing Company.
- National Research Council of Canada (NRCC). 1986. *Alternative Energy Technology in Canada*. NRC's Energy R & D Program 1975 — 1985. Energy Division, NRCC.
- Nkemdirim, L.C. 1981. *A Solar Energy Atlas for Alberta*. Volume I. Energy Resources Research Fund and Alberta Department of Energy and Natural Resources.
- Passmore Associates International. 1987. *The Private Power Option for Canada*. Passmore Associates International, Ottawa.
- Paterson, B.A., D.R. Baker, and N.E. Jensen. 1985. *Evaluation of Small Scale Wind Turbines for Pumping Water in Alberta*. Farming for the Future and Alberta/Canada Energy Resources Research Fund.

- Pulfrey, D.L. 1977. "Photovoltaic Power Systems: The Present and The Future." Paper presented at *Solar Energy Update '77*, 3rd Annual General Meeting and Conference, Solar Energy Society of Canada. August 22 - 24, 1977.
- Ross, W.A., H.R. Boerma, and D.B. Brooks. 1985. *Energy Requirements in Alberta 1983 to 2010*. Environmental Resource Center, Edmonton.
- Schrecker, T. 1983. *The Conserver Society Revisited*. Discussion Paper D83/3. Science Council of Canada.
- Science News*. 1987. "Solar Cells That Work In The Dark." 132 (November 21):325.
- Segal, R. 1977. "1976 — 2000: An Energy Proposal." Paper presented at *Solar Energy Update '77*, 3rd Annual General Meeting and Conference, Solar Energy Society of Canada. August 22 - 24, 1977. Edmonton.
- SOL. 1987. "Industry News." 60 (July-August): 4.
- _____. 1988. "TPK Signs Major Contracts in India." 63 (March-April): 5.
- Touche Ross. 1988. *An Assessment of the Costs and Benefits of an Ethanol Industry in Alberta*. Touche Ross Management Consultants, Edmonton.

Appendix A

Members of the Energy and Non-Renewable Resources Sub-Committee

This paper began as a project under the auspices of the Energy Sub-Committee in early 1986. In late 1986, this group merged with the Non-Renewable Resources Sub-Committee, which assumed responsibility for the paper. Listed below are those persons who served on the Energy Sub-Committee and the Energy and Non-Renewable Resources Sub-Committee at some time during the preparation of this paper.

Mrs. S. Ambergcombie — Unaffiliated

Mr. D. Broughton — Unaffiliated

Dr. W. Buchta — Northern Alberta Institute of Technology

Mr. G. Cameron — Edmonton Chamber of Commerce

Mr. D.A. Clarke — Southern Alberta Institute of Technology

Dr. R. Gehrke — Alberta Chiropractic Association

Mrs. M. Goodwin — Alberta Women's Institute

Mrs. H. Heacock — Calgary Local Council of Women

Mr. J. Hirsch — City of Medicine Hat

Ms. J. Hodgson — Calgary Chamber of Commerce

Mrs. B. Hunter — Consumer's Association of Canada

Mr. A. Kennedy — Coal Association of Canada

Mr. R.G. Kuhn — University of Alberta

Dr. A. Lamb — Alberta Chamber of Commerce

Mr. P. Lulman — Coal Association of Canada

Prof. H. Madill — University of Alberta

Mrs. E. Martin — Outdoors Unlittered

Mr. J. McLaughlin — Alberta Association, Canadian Institute of Planners

Mr. D. Moffat — Alberta Federation of Labour

Ms. S. Nelson Pier — Calgary Local Council of Women

Mrs. A. Parkinson — Community Planning Association of Alberta

Mrs. E. Paschen — Unaffiliated

Mr. G. Paschen — Archeological Society of Alberta

Mr. B. Peel — Electric Utility Planning Council

Mr. D. Porter — Canadian Petroleum Association

Dr. J.E. Rapson — Solar Energy Society (Calgary Chapter)

Dr. W.A. Ross — University of Calgary

Dr. F. Siddiqui — Northern Alberta Institute of Technology

Mr. J.E. Staples — Association of Professional Engineers, Geologists and Geophysicists of Alberta

Mr. B. Staszenski — Save Tomorrow Oppose Pollution (STOP)

Mr. S.E. Stephansson — Alberta Oil Sands Industry Environmental Association

Mrs. M. Stephenson — Alberta School Trustees

Mr. G. Stewart — Unaffiliated

Mr. N. White — Unaffiliated

EEAC Liaison Member — Dr. J. Godfrey

SAC Liaison Member — Dr. D. Kvill

N.L.C. - B.N.C.



3 3286 08349242 7